USDA-ARS North Appalachian Experimental Watershed: 70-Year Hydrologic, Soil Erosion, and Water Quality Database

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Hydrologic data from agricultural watersheds are necessary to identify long-term trends and to develop and validate hydrologic and water quality models. These types of data have been collected for 70 yr at the North Appalachian Experimental Watershed (NAEW) near Coshocton, OH. The NAEW has 19 small (0.5–3.0-ha), single-land-use watersheds for which surface runoff data have been collected year round on an event basis for various time periods since 1939. There are six large (17–123-ha), mixed-use watersheds with perennial streams where flow is measured continuously. Hydrologic data have been collected from 11, 2.4-m-deep, 8.1-m^2 surface area monolith lysimeters. Meteorological, land management, and soil property data are available. Water quality data have been collected from watersheds and lysimeters since the early 1970s. Collaborative research efforts utilizing this resource are encouraged; the NAEW web site (www.ars.usda.gov/mwa/coshocton; verified 19 Dec. 2009) has detailed information on the types of available data. Data are available through the authors.

Abbreviations: NAEW, North Appalachian Experimental Watershed; WS, watershed.

Long-term hydrologic databases are important to private and government entities at local, state, and federal levels. Collecting integrated data on watersheds, especially where multiple watersheds are monitored, requires a major commitment of resources. Federal agencies are the primary entities capable of committing to the task of collecting such data on a watershed basis. It is important that all who might have a need for such data and who have an interest in working collaboratively be made aware of these databases, including details on the kinds of data available.

The 420-ha NAEW (40°22′ N, 81°48′ W) near Coshocton, OH, was established in the mid-1930s to address the soil erosion problems of the time. Several experimental watersheds were established across the United States at this time by the USDA Soil Conservation Service, now the Natural Resources Conservation Service (Harmel et al., 2007). The NAEW site is one of only two of these original watershed sites that remain in operation. (The other site is the Grassland Soil and Water Research Laboratory near Reisel, TX, and the dominant soils are Vertisols; Harmel et al., 2007). This site was selected because it is typical of 130,000 km^2 of unglaciated land in southeast Ohio, western Pennsylvania, and most of West Virginia, with residual soils developed mainly from relatively flat-lying strata of acid sandstones and shales. Generally, the upland valleys are narrow and steep, and there is little land level enough to provide large volumes of runoff storage (Kelley et al., 1975). In the mid-1960s, newer land management practices, e.g., no-till and conservation tillage, began to be evaluated in terms of their potential to reduce runoff and erosion (Kelley et al., 1975). The impacts of several grazing systems continue to be evaluated with regard to runoff and soil loss.

We hope that increased awareness of this database will result in greater research collaboration and utilization of this important data resource. This database is a major resource because of its 70-yr length, detail of data collection, year round rather than seasonal data collection, and precision of instrumentation.

HYDROLOGIC DATABASE

Runoff Data

During the establishment of the NAEW in the mid-1930s, 25 small (0.5–3.0-ha) "single vegetative cover" watersheds were established in the unglaciated part of Ohio in swale areas on hilltops, and data collection was initiated (Fig. 1). The watershed slopes range from 2 to 35%, with individual watershed slope averages ranging from 7 to 20%. Soils are well-drained residual silt loams (Typic Dystrochepts and Hapludults and Aquic Hapludalfs) (Kelley et al., 1975).

For various reasons, data collection was discontinued on a few watersheds after only a few years. Currently, runoff and water quality data are being collected on 19 small watersheds (Table 1), as indicated by the watersheds with data collection to the present. Hydrologic data collection was temporarily discontinued on many of these watersheds, usually due to a need to upgrade the monitoring structures (Table 2), but there is still an average of >60 yr of data for each watershed. Surface runoff from the small watersheds is currently measured using precalibrated H-flumes, and flow-proportional water samples are collected for each event using Coshocton wheels (Brakensiek et al., 1979).

When the small watersheds were first established, runoff and erosion were measured from improved agricultural practices and compared with the prevailing practices. Improved practices included higher fertilizer rates, contour plowing and planting instead of straight rows on slopes, improved methods of utilizing manure, and better cultivars (Kelley et al., 1975). The small watersheds are natural, topographic drainage areas, and berms were added to clearly mark the boundaries. As conservation options increased, management practices evaluated on the small watersheds were revised to include greater herbicide use, conservation tillage, no-till, and a variety of pasture management systems (Table 3).

There are six larger watersheds (17–123 ha) that have perennial streams. Two were established in the late 1930s and four in the 1960s (Table 2). Broad-crested weirs (Brakensiek et al., 1979) are used to measure flow and are equipped with Coshocton vane samplers

Soil Sci. Soc. Am. J. 74:619–623
Published Online 28 Dec. 2009
doi:10.2136/sssaj2009.0196N
Received 20 May 2009.
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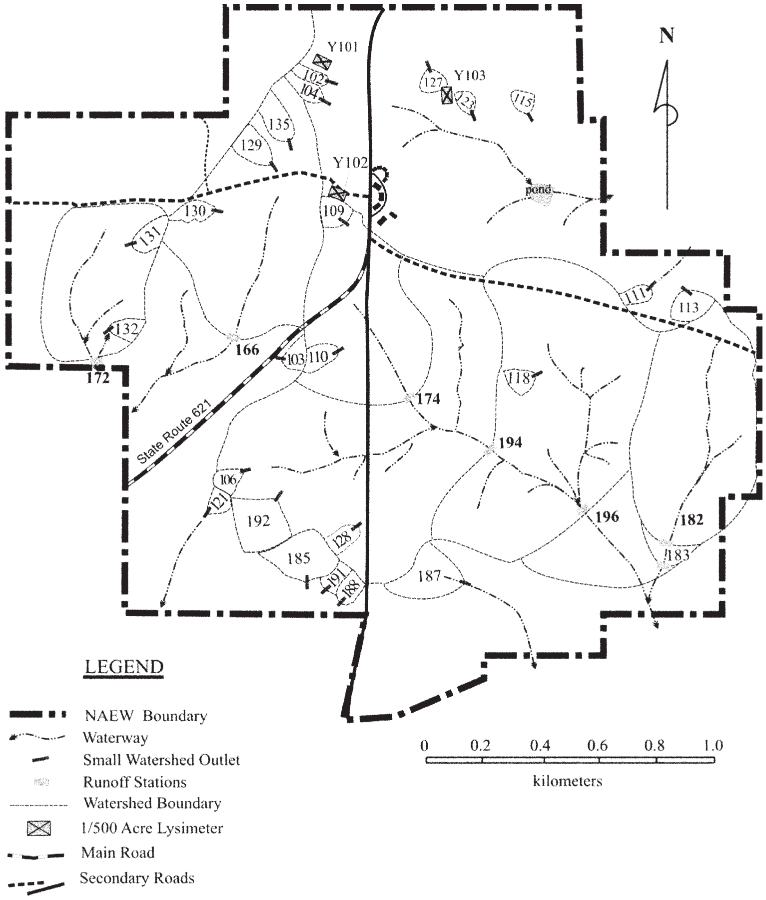

Fig. 1. Map of the USDA-ARS North Appalachian Experimental Watershed (NAEW) near Coshocton, OH. Small and large watersheds as well as 8.1-m^2 lysimeter locations are shown.

(Edwards et al., 1976) so that flow-proportional storm samples can be obtained in addition to base-flow grab samples. These watersheds have mixed land management: all wooded (Watershed [WS] 172); 82% unimproved pasture and 18% wooded (WS 182); 57% meadow and fertilized pasture, 34% wooded, and 9% cropland (WS 196); and 57% meadow and fertilized pasture, 32% cropland, and 11% wooded (WS 166) (Owens et al., 2008). Some of the small watersheds are within some of the larger watersheds in upland positions. Three of the larger watersheds are "nested" in each other (WS 174 in WS 194 in WS 196).

In the stratigraphy of the unglaciated landscape, there are nearly impermeable clay layers underlying coal seams. Subsurface water flows to the soil surface where these clay layers outcrop along the hillslopes. Some of these "seeps" have been developed into springs. Using HS-flumes or V-notch weirs, flow is being measuring at three of these springs under grazing areas (Owens and Bonta, 2004).

Lysimeter Data

Hydrologic data (Table 1) including percolation and surface runoff are available from each of 11 monolith lysimeters (located at Y101, Y102, and Y103), which were constructed in the 1930s. Percolation and runoff are collected in their respective tanks for each lysimeter, and each tank is equipped with an FW-1 chart recorder to measure the water depth. Each lysimeter has a surface area of 8.1 m^2 and a depth of 2.4 m. These lysimeters (two sets of four and one set of three) are soil blocks enclosed by constructing concrete casings on location on the ground surface. The casings were lowered into the soil profile after removing the soil below the cutting edge of the casing, allowing them to sink to 2.4-m depth. Afterward, perforated steel percolation pans were forced into the fractured bedrock at the bottom edge of the casing to complete the isolation of the soil monolith. This construction was done without disturbing the soil profile or the underlying fractured bedrock (Harrold and Dreibelbis, 1958). Each set of lysimeters receives a surface management practice similar to an adjacent small watershed: Y101, WS 102 (Owens et al., 1999); Y102, WS 109 (Owens, 1987); and Y103, WS 123 (Owens et al., 2000); the watershed management records also describe the surface management of the lysimeters. Records were discontinued on Y102 and Y103 after 2003 due to a lack of resources. Each set of lysimeters is on a different soil type, as described by Kelley et al. (1975): Y101 is Dekalb (a loamy-skeletal, siliceous, active, mesic Typic Dystrudept); Y102 is Berks/Rayne (a loamy-skeletal, mixed, active, mesic Typic Dystrochrept/fine-loamy, mixed, active, mesic Typic Hapludult); and Y103 is Keene (a fine-silty, mixed, superactive, mesic Aquic Hapludalf). One lysimeter at each site sits on an automatically recording scale so that actual evapotranspiration and precipitation are measured. Each lysimeter has a mass of approximately 59 Mg, and with the three on scales, differences of 0.5 kg can be measured. The other eight lysimeters are similarly constructed but are not on scales. Because of the length of time that these lysimeters have been monitored, the soils have long been stabilized with their walls and the data are quite reliable.

Soil Loss and Water Quality Data

Soil loss data are available for most of the small watersheds (Table 2) for the years that runoff data were collected. The earliest records available began in 1942. Tillage management was the major factor affecting soil loss (Harrold, 1949; Harrold et al., 1967). Usually there was no soil loss from the watersheds in meadow, including the meadow years of the 4-yr rotation (Edwards and Owens, 1991) (Table 3). Some soil loss occurred from pasture watersheds, especially those used for wintering cattle (Owens et al., 1997). Soil loss amounts varied from moderate to excessive from watersheds with row crops, especially from continuous, moldboard-plowed corn watersheds. During the early years with the 4-yr rotations, management was either "prevailing" or "improved" practices (Edwards et al., 1973). Management records are available for all small watersheds and starting in the 1970s, nutrient and major cation and anion loss data began to be collected on a regular basis for all watersheds and lysimeters.

Meteorological Data

Meteorological parameters were among the first data collected at the NAEW. Collection of air temperature, 10-m wind run, solar radiation, A-pan evaporation, and average dew point data began in 1939 and continues to the present (Table 1). In 1990, the collection of meteorological parameters was increased to include: barometric pressure, 10-m wind speed and direction, A-pan wind run, and A-pan water temperature. Soil temperature and soil moisture measurements at a variety of depths down to 61 cm are also available (Table 1). Recording precipitation data are collected using weighing-bucket precipitation gauges and have been collected at the NAEW at as many as 22 gauges for different durations of monitoring. Currently, the NAEW precipitation-gauge network consists of 11 gauges.

Table 1. Types of data collected at the North Appalachian Experimental Watershed, near Coshocton, OH.

Type of data	Years	Type of instrumentation	Frequency of data collection
Precipitation, 11 stations	1938–present	weighing bucket†	breakpoint
Runoff			
19 small watershed stations	see Table 2	H-flumes, drop-box weirs	breakpoint
6 larger watershed stations	see Table 2	broad-crested weirs	breakpoint
Spring (3 stations)	1984–present	HS- & V-notch flumes	breakpoint
Lysimeter data: 3 weighing lysimeters & 8 nonweighing lysimeters‡			
Runoff	1945–present, Y101 1945–2003, Y102 & Y103	tank	daily
Lysimeter precipitation	1945–present, Y101 1945–2003, Y102 & Y103	computed	daily
Percolation	1945–present, Y101 1945–2003, Y102 & Y103	tank	daily
Evapotranspiration	1945–present, Y101 1945–2003, Y102 & Y103	computed	daily
Meteorological data			
Air temperature	1939–present	hygrothermograph, max./min. thermometer	hourly, daily avg., daily max./min.
Barometric pressure	1990–present	barometer	hourly
10-m wind speed	1990–present	cup anemometer	hourly
10-m wind run	1939–present	cup anemometer	daily
10-m wind direction	1990–present	wind vane	hourly
Solar radiation	1990–present	solar radiometer	hourly
Solar radiation	1939–present	solar radiometer	daily
Evaporation	1939–present	class A pan §	0800 h, April–Sept.
Evaporation	1990–present	class A pan §	2400, 24-h total, April–Sept.
Wind run	1990–present	cup anemometer	0800 h and 2400, 24-h total, April–Sept.
Water temperature	1990–present	max./min. Hg thermometer	0800 h, April–Sept., max./min.
Average dew point	1939–1989, 2007–present	sling psychrometer, chilled mirror¶	daily
Soil data			
10-cm soil temperature bare#	1990–present	thermocouple	0800 h, 24-h max./min.
10-cm soil temperature grass#	1990–present	thermocouple	0800 h, 24-h max./min.
Soil moisture	mid-1940s–present	gravimetric, gypsum blocks, neutron & capacitance probes	varies monthly
Soil temperature at 1.3 cm	1990–present	thermocouple	every 6 h
Soil temperature at 8 cm	1990–present	thermocouple	every 6 h
Soil temperature at 15 cm	1990–present	thermocouple	every 6 h
Soil temperature at 30 cm	1990–present	thermocouple	every 6 h
Soil temperature at 61 cm	1990–present	thermocouple	every 6 h

† A collecting bucket rests on a weighing platform, which lowers with increasing weight. This deflection is recorded on a graduated revolving chart (Brakensiek et al., 1979).

‡ Lysimeters are undisturbed blocks of soil with 8.1-m^2 surface area and a depth of 2.4 m; each lysimeter is approximately 59 Mg. Weighing lysimeters are each on a scale that measures a weight changes of 0.5 kg; nonweighing lysimeters are not on scales but have all the other measuring devices.

§ A standard size pan containing water so that evaporation is measured by the drop in water level (Brakensiek et al., 1979).

¶ Instruments for measuring water vapor in the air at the time dew drops form.

Longer records are available but not on magnetic media.

RESEARCH OPPORTUNITIES

These NAEW databases present excellent opportunities to investigate a variety of land use relationships and to provide input to models. An awareness of the length and extensiveness of these databases should prompt investigations that can be pursued in collaboration with NAEW scientists. The following are some potential areas of collaboration.

Climate Change

The NAEW database is an excellent resource for evaluating trends in seasonal and overall temperature changes, increasing length of the growing season, changes in precipitation patterns, and other climate change aspects.

Experimental Watersheds as Analogues for Other Land Conditions

The NAEW watershed practices can serve as analogs for other land alterations and best management practice development, such as runoff reduction practices to control urban runoff. The NAEW precipitation–runoff databases have been used in curve number development and verification (Bonta, 1997; Hawkins et al., 2009), and they offer unique opportunities to develop curve numbers for other conditions such as frozen soils, disturbed landscapes, and agricultural lands.

Precipitation Characterization

A probabilistic representation of rainfall distribution ("Huff curves") (Bonta, 2004) has been investigated at the NAEW for precipitation patterns, and further studies are needed to maximize the information obtained from these. Improved characterization of

Table 2. Years of watershed hydrologic data at the North Appalachian Experimental Watershed.

Watershed ID	Time period	Total record
		yr
	Small watersheds currently in operation	
102	1937–1946, 1957, 1960–present	60
103	1939–1970, 1973–present	68
104	1936–1946, 1969–1972, 1974–present	50
106	1940–1972, 1974–present	68
109	1938–present	71
110	1939–1970, 1974–present	67
111	1939–1970, 1989–present	52
113	1939–1973, 1975–1976, 1983–present	63
115	1939–1970, 1982–present	59
118	1940–1973, 1975–1976, 1982–present	63
121	1939–1970,1972, 1974–present	68
123	1939–present	70
127	1949–1970, 1983–present	48
129	1938–1972, 1974–present	70
130	1938–1971, 1979–present	64
135	1938–1969, 1974–present	67
185	1939–1972, 2005–present	38
191	1939–1946, 1948, 1952–1954, 1956–1957, 1960–1972, 1979–present	57
192	1940–1970, 1974–present	66
	Small watersheds not in operation	
128	1939–1947, 1950, 1964, 1958–1972	26
131	1938–1969, 1975–1981	39
132	1948–1969	22
187	1941–1972	32
188	1939–1970	32
	Larger watersheds	
166	1967–1972, 1975–present	40
172	1939–1972, 1975–present	68
174	1960–1977, 1979–present	48
182	1964–1971, 1974–present	43
183	1938–1963 (gauging station shifted slightly upstream to Watershed 182)	26
194	1960–2005	46
196	1937–present	72

Table 3. Small watershed management practices.

Practice	Watersheds	Watershed-years	Time period
	no.	no.	
4-yr rotation (corn–wheat–meadow–meadow)	17	520	1940–1974
Continuous corn			
Moldboard plowed	4	16	1971–1982
Disk-tilled	1	3	2006–present
No-till	13	154	1964–present
Corn–soybean rotation			
No-till	2	44	1984–2005
Chisel-plow	2	44	1984–2005
Para plow	2	12	1984–1989
3-yr rotation (corn–soybean–wheat/clover), disk	3	48	1990–2005
Pasture			
Continuous	9	133	1939–1973, 2005–present
Rotational	9	252	1974–present
Meadow (not grazed)	16	138	1939–present
Oat	14	14	1939
Other	10	19	1945–present

precipitation in general would provide inputs to models for ungauged areas.

Management to Mitigate Potential Flooding

In addition to human and property losses, flooding causes great environmental problems. Greater understanding of the interaction between the amounts and intensities of precipitation and physical and anthropogenic characteristics of the land on which it falls in space and time can lead to practices that diminish flooding impacts under agricultural and urban conditions. Improved methodologies to estimate the effects of these practices can lead to economical and effective land management implementation.

Quantifying the Evaporation–Transpiration Component of the Hydrologic Cycle

There are more sources for rainfall and runoff data than for evapotranspiration (ET) data. The NAEW lysimeter database includes ET data. Even though the lysimeter data have had considerable use (McGuinness and Parmele, 1972), opportunities have not been exhausted. The ET data have been used very sparingly during the last 35 yr. Such data can be used to increase our understanding of plant water-use efficiencies in the humid United States.

Validating and Refining Water Quality and Chemical Transport Models

Data on nutrient and major ion transport are available at multiple scales (i.e., small and large watersheds) and from the lysimeters, wells, and spring developments. This information can be used to investigate models that assess the effects of agricultural management practices and models that investigate geochemical cycles. A 14-yr database on losses of selected herbicides in surface runoff is also available (Shipitalo and Owens, 2003; Shipitalo et al., 2008).

Use of Data for Long-Term and Emerging Issues

Hydrologic, soil loss, and water quality databases of this length, detail, and quality are rare. In a long-term analysis, Owens et al. (2008) compared water quality response times in small and large watersheds during a 25-yr period. Data collected from the NAEW have been used to address problems for which they were not originally designed. Examples are urban hydrology (Bonta et al., 2003), evapotranspiration landfill caps (Hauser et al., 2005), pathogen transport, frozen soil, macropore modeling (Shipitalo et al., 2000), climate change, and groundwater recharge studies (Bonta and Muller, 1999). Collaborative research is needed to further explore the utility of these databases for these and other topics.

Scientists interested in collaborative efforts with NAEW scientists using these databases are invited to contact us. The data are in MS Word and Excel formats, and the farm management records are in an Access database. All proposals to utilize these resources will be considered on their merits, the suitability of the databases to the proposal, and the likelihood of achieving publishable results. Discussions of a potential database use before developing a proposal are also welcome. Because of its long period of collection, number of sites, number of parameters collected, detail of record, and soil properties, the NAEW database is unique and not found elsewhere in the United States.

REFERENCES

Bonta, J.V. 1997. Determination of watershed curve number using derived distributions. J. Irrig. Drain. Eng. 123:28–36.

Bonta, J.V. 2004. Development and utility of Huff curves for disaggregating precipitation amounts. Appl. Eng. Agric. 20:641–653.

Bonta, J.V., and M. Muller. 1999. Evaluation of the Glugla method for estimating evapotranspiration and groundwater recharge. Hydrol. Sci. J. 44:743–761.

Bonta, J.V., W. Shuster, E. Warnemuende, H. Thurston, D. Smith, M. Gross, and H. Cabezas. 2003. Quantification of urbanization in experimental watersheds. p. 355–364. *In* K.G. Renard et al. (ed.) Interagency Conf. on Res. in the Watersheds, 1st, Benson, AZ. 27–30 Oct. 2003. U.S. Gov. Print. Office, Washington, DC.

Brakensiek, D.L., H.B. Osborn, and W.J. Rawls (Coord.). 1979. Field manual for research in agricultural hydrology. Agric. Handbk. 224. U.S. Gov. Print. Office, Washington, DC.

Edwards, W.M., H.E. Frank, T.E. King, and D.R. Gallwitz. 1976. Runoff sampling: Coshocton vane proportional sampler. ARS-NC-50. U.S. Gov. Print. Office, Washington, DC.

Edwards, W.M., J.L. McGuinness, D.M. Van Doran, Jr., G.F. Hall, and G.E. Kelley. 1973. Effect of long-term management on physical and chemical properties of the Coshocton watershed soils. Soil Sci. Soc. Am. Proc. 37:927–930.

Edwards, W.M., and L.B. Owens. 1991. Large storm effects on total soil erosion. J. Soil Water Conserv. 46:75–78.

Harmel, R.D., J.V. Bonta, and C.W. Richardson. 2007. The original USDA-ARS experimental watersheds in Texas and Ohio: Contributions from the past and visions for the future. Trans. ASAE 50:1669–1675.

Harrold, L.L. 1949. Soil loss as determined by watershed measurements. Agric. Eng. 30:137–140.

Harrold, L.L., and F.R. Dreibelbis. 1958. Evaluation of agricultural hydrology by monolith lysimeters 1944–55. USDA Tech. Bull. 1179. U.S. Gov. Print. Office, Washington, DC.

Harrold, L.L., G.B. Triplett, and R.E. Youker. 1967. Watershed test of no tillage corn. J. Soil Water Conserv. 22:98–100.

Hauser, V.L., D.M. Gimon, J.V. Bonta, T.A. Howell, R.W. Malone, and J.R. Williams. 2005. Models for hydrologic design of evapotranspiration landfill covers. Environ. Sci. Technol. 39:7226–7233.

Hawkins, R.H., T.J. Ward, D.E. Woodward, and J.A. Van Mullem (ed.). 2009. Curve number hydrology, state of the practice. Am Soc. Civ. Eng., Reston, VA.

Kelley, G.E., W.M. Edwards, L.L. Harrold, and J.L. McGuinness. 1975. Soils of the North Appalachian Experimental Watershed. USDA-ARS Misc. Publ. 1296. U.S. Gov. Print. Office, Washington, DC.

McGuinness, J.L., and L.H. Parmele. 1972. Maximum potential evapotranspiration frequency: East central U.S. J. Irrig. Drain. Div. Am. Soc. Civ. Eng. 98:207–214.

Owens, L.B. 1987. Nitrate leaching losses from monolith lysimeters as influenced by nitrapyrin. J. Environ. Qual. 16:34–38.

Owens, L.B., and J.V. Bonta. 2004. Reduction of nitrate leaching with haying or grazing and omission of nitrogen fertilizer. J. Environ. Qual. 33:1230–1237.

Owens, L.B., W.M. Edwards, and R.W. Van Keuren. 1997. Runoff and sediment losses resulting from winter feeding on pastures. J. Soil Water Conserv. 52:194–197.

Owens, L.B., W.M. Edwards, and R.W. Van Keuren. 1999. Nitrate leaching from grassed lysimeters treated with ammonium nitrate or slow-release nitrogen fertilizer. J. Environ. Qual. 28:1810–1816.

Owens, L.B., R.W. Malone, M.J. Shipitalo, W.M. Edwards, and J.V. Bonta. 2000. Lysimeter study of nitrate leaching from a corn–soybean rotation. J. Environ. Qual. 29:467–474.

Owens, L.B., M.J. Shipitalo, and J.V. Bonta. 2008. Water quality response times to pasture management changes in small and large watersheds. J. Soil Water Conserv. 63:292–299.

Shipitalo, M.J., W.A. Dick, and W.M. Edwards. 2000. Conservation tillage and macropore factors that affect water movement and the fate of chemicals. Soil Tillage Res. 53:167–183.

Shipitalo, M.J., R.W. Malone, and L.B. Owens. 2008. Impact of glyphosate-tolerant soybean and glufosinate-tolerant corn production on herbicide losses in surface runoff. J. Environ. Qual. 37:401–408.

Shipitalo, M.J., and L.B. Owens. 2003. Atrazine, deethylatrazine, and deisopropylatrazine in surface runoff from conservation tilled watersheds. Environ. Sci. Technol. 37:944–950.